Cognitive Functioning In Long Duration Head-Down Bed Rest

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ABSTRACT

INTRODUCTION: The Space Flight Cognitive Assessment Tool for Windows (WinSCAT) is a self-administered battery of tests used on the International Space Station for evaluating cognitive functioning. Here, WinSCAT was used to assess cognitive functioning during extended head-down bed rest. **METHODS:** Thirteen subjects who participated in 60 or 90 days of 6° head-down bed rest took WinSCAT during the pre-bed rest phase, the in-bed rest phase, and the post-bed rest (reconditioning) phase of study participation. **RESULTS:** After adjusting for individual baseline performance, 12 off-nominal scores were observed out of 351 total observations during bed rest and 7 of 180 during reconditioning. No evidence was found for systematic changes in off-nominal incidence as time in bed rest progressed, or during the reconditioning period. **DISCUSSION:** Cognitive functioning does not appear to be adversely affected by long duration head-down bed rest. Individual differences in underlying cognitive ability and motivation level are likely explanations for the current findings.

KEY WORDS: WinSCAT, space flight, cognitive function assessment tool

INTRODUCTION

The Space Flight Cognitive Assessment Tool for Windows (WinSCAT) was originally developed for medical operations at NASA's Johnson Space Center in Houston, Texas. WinSCAT has been validated (4) and implemented with astronauts from fifteen expeditions on the International Space Station (ISS). It is currently a medical requirement for all U.S. long-duration crewmembers and is administered every 30 days throughout the ISS missions and after any physical injury or insult to the central nervous system (e.g., exposure to increased levels of carbon dioxide).

The purpose of the WinSCAT is to provide ISS crew surgeons with an objective clinical tool to monitor the astronauts' cognitive status during long-duration space flight (2). WinSCAT addresses a critical need because an unexpected event, a medical condition, or the cumulative effects of space flight could negatively affect an astronaut's cognitive status. Of particular concern are cognitive changes due to illness, injury, toxic exposure, decompression accidents, medication side effects, or excessive exposure to radiation that could impact an astronaut's ability to successfully perform flight tasks and threaten mission success. Risks related to cognitive capabilities, as well as psychosocial adaptation and neurobehavioral problems, have been recognized as critical for exploration missions to Mars (1). WinSCAT is a computer-based, self-administered battery of five cognitive assessment subtests. WinSCAT requires dichotomous responses via mouse or keypad and is designed for repeated-measures applications. In 11 to 15 minutes, WinSCAT assesses response time, sustained attention/concentration, visual working memory, and verbal working memory, scoring performance in four categories corresponding to specific tasks. Here, WinSCAT was used to assess cognitive functioning in a long-duration bed rest study. Overall cognitive functioning was not expected to be negatively affected by extended head-down bed rest.

METHODS

Refer to Meck, et al. (3) for description of the protocol and general conditions of the studies, and the use of long-duration head-down bed rest as a model for space flight. Bed rest and test protocols were reviewed and approved by the Johnson Space Center Committee for the Protection of Human Subjects, the UTMB Institutional Review Board, and UTMB General Clinical Research Center Science Advisory Committee. Subjects received verbal and written explanations of the bed rest and test protocols before providing written informed consent.

Thirteen subjects (five females and eight males) took the WinSCAT test battery on a Dell Latitude D600 notebook computer. **Table I** describes the individual subtests of the WinSCAT test. During the pre-bed rest (ambulatory) phase, WinSCAT was administered six times. The first three administrations were for orientation and training/familiarization, and the next three administrations established each subject's individual baseline. During the head-down bed rest phase, WinSCAT was scheduled to be administered two times for subjects 1 through 3 (60 days of bed rest) and four times for subjects 4 through 13 (90 days of bed rest). During the reconditioning period, WinSCAT was scheduled to be administered twice. Due to a hurricane evacuation affecting subjects 8 through 11, three WinSCAT tests were administered during the bed rest phase, and two of the subjects agreed to take one final test during their reconditioning period.

Testing was conducted with the subject seated on his or her bed (during ambulatory periods) or lying on the bed or gurney at 6° head-down tilt. Subjects chose to take the test either with the computer supported on a bedside table at an appropriate height and angle, or propped on their knees. When possible, testing was not conducted within 30 minutes of eating a meal or within two hours of taking a similar cognitive test. Efforts were made to minimize distractions to provide a quiet testing environment free from interruptions.

RESULTS

Performance on the WinSCAT is assessed in terms of accuracy scores and response times. Each test administration yields a total of nine scores, including response time for four subtests, accuracy scores for four subtests, and number of lapses (missed items) on CPT. Improved performance is reflected by increased accuracy, decreased response time, or fewer missed items. Response times and accuracy scores were further reduced into throughput scores. Throughput is a measure of cognitive efficiency taking both accuracy and response time into account and providing an estimate of correct responses per minute for each subtest. Accordingly, throughput is higher (indicating better cognitive efficiency) when accuracy is high and response time is low, and throughput is lower when accuracy is low and response time is high. Because the hard cutoffs automatically generated by the WinSCAT software to determine off-nominal accuracy scores were developed for astronauts rather than the general population, we revised the definition of "off-nominal" to correct for possible differences in cognitive ability between study participants and astronauts. Therefore, we defined off-nominal performance for accuracy scores as a 20 to 25% decrement from each subject's individual baseline (see "Off-Nominal Rules" in **Table III** for definitions of all off-nominal observations).

Overall incidence of off-nominal scores by bed rest and subtest type (accuracy and response time or throughput) is shown in **Table II**. Statistical inference on the effect of bed rest and subtest category (CPT, MTH, MTS, or CDD) on the incidence of off-nominal responses was made using generalized estimating equations (GEE) with a binomial family, logit link function and robust variance estimation (5) to account for repeated observations pertaining to the same subject. GEE analyses were made separately for the original nine subtest measures and for the four throughput measures.

Accuracy and Response Time

As expected, there was considerable variability in subject performance. **Table III** presents the off-nominal subtest scores for each subject, relative to their individual baseline performance. Using the revised definitions for off-nominal accuracy scores, five of the 13 subjects performed consistently throughout head-down bed rest with no off-nominal scores, and six subjects had only one off-nominal score during bed rest. Subject 7, who had the highest number of off-nominal events, accounted for four off-nominal scores, with three of the off-nominal scores occurring on MTH accuracy and one off-nominal score on CPT response time. Subtest measures with the highest number of off-nominal events were MTH accuracy (33%) and CPT accuracy (17%). MTS accuracy was the only subtest measure that had no off-nominal scores. Regression analysis with GEE showed no significant trend in the incidence rate of off-nominal scores for accuracy and response time measures during bed rest ($z = -.40$, $p = .69$), nor was there any significant difference between incidence rates during vs. post bed rest ($z = .52$, $p = .61$). Also, over all time periods, no significant differences were found between incidence rates in the four subtest categories.

Throughput

Table IV presents subjects' number of off-nominal throughput scores for four WinSCAT subtests (defined relative to their individual baseline performance). Again, individual variability persists. Subject 7, who accounted for the most off-nominal accuracy and response time scores also had the most off-nominal throughput scores (3 on MTH). Eight of the 13 subjects did not produce any off-nominal throughput scores. No evidence was found for increased off-nominal incidence during bed rest ($z = -0.03$, $p = 0.98$) or between in- and post-bed rest overall ($z = -0.05$, $p = 0.96$).

DISCUSSION

WinSCAT is a computer-based test platform designed to assess cognitive functioning of astronauts during space flight. Though overall cognitive functioning of bed rest subjects was not expected to change, WinSCAT is a medical requirement for U.S. crewmembers on long duration space flight missions and is therefore integrated into bed rest testing.

Not surprisingly, the data show variability between subjects. If extended head-down bed rest had a negative effect on overall cognitive functioning, consistent decrements would be expected to be found with all subjects across time. Using the cutoff rules automatically generated by the WinSCAT software, a number of off-nominal scores were observed, but no consistent patterns were detected. After adjusting for individual baseline performance, no evidence was found for increased off-nominal incidence either during or after bed rest, or as time in bed rest progressed. As expected, overall cognitive functioning does not appear to be adversely affected by long duration head-down bed rest. Given the small sample size, findings should be interpreted with caution. In general, cognitive tests tend to be sensitive to distractions and motivation of the subjects; therefore, distractions, motivation level, and individual differences in underlying cognitive ability are possible explanations for the results found in this study. Further, the apparent differences in the cognitive ability of the average bed rest subject and the average astronaut could limit the generalizability of these findings to the astronaut corps.

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Table I. Subtests of WinSCAT.

Code Substitution Learning (CDS)	
Description:	A memory stimulus task, the test-taker is asked to determine if a symbol-number pair has been correctly matched by evaluating it against a reference grid at the top of the screen. The purpose of this subtest is for the test-taker to learn the correct pairings of symbols and numbers to recall the symbol-number pairs for the Code Memory Delayed (final) subtest in the battery.
Summary Results:	No summary results are displayed because this is a learning task.
Running Memory Continuous Performance (CPT)	
Description:	An attention and concentration task, the test-taker is asked to track the presentation of 160 numbers by comparing the number on screen at the moment with the number that immediately preceded it.
Summary Results:	Median response time, percent correct responses, and number of lapses (failure to respond within 700 milliseconds)
Mathematical Processing (MTH)	
Description:	A mathematics achievement task, the test-taker is asked to perform simple addition and subtraction on three single digit numbers (e.g., 3-5+4=, 5+3-6=). The test-taker then indicates whether the resulting answer is less than or greater than five.
Summary Results:	Median response time and percent of correct responses
Delayed Matching to Sample (MTS)	
Description:	A visual memory task, the test-taker is asked to identify which of two grids appearing on screen is identical to a sample grid that appeared prior to a delay of five seconds.
Summary Results:	Median response time and percent of correct responses
Code Memory Delayed (CDD)	
Description:	A short-term memory task, the test-taker is asked to recall the symbol-number pairs s/he learned earlier during the CDS task and to determine if a symbol-number pairing on the screen is correct.
Summary Results:	Median response time and percent of correct responses

__Table II.__ Overall Incidence of Off-Nominal Scores by Bed Rest and Subtest Type

	Accuracy/ Response Time	**Throughput**
In Bed Rest	12/351	8/156
Post Bed Rest	7/180	4/80
Total	**19/531**	**12/236**

Note: The total numbers of observations for GEE analyses are the denominators in the above fractions.

Table III. WinSCAT Summary by Subject: Off-Nominal Subtest Scores (Medians)

ID	Total Off-Nominal		Off-Nominal Scores by Subtest *								
	Off-Nominal Rules		≥20%	≤20%	>4	>25%	≤20%	>25%	≤20%	>25%	≤20%
	Count	Percent	**CPTRT**	**CPTA**	**CPTL**	**MTHRT**	**MTHA**	**MTSRT**	**MTSA**	**CDDRT**	**CDDA**
1	0	0.0%	0	0	0	0	0	0	0	0	0
2	0	0.0%	0	0	0	0	0	0	0	0	0
3	0	0.0%	0	0	0	0	0	0	0	0	0
4	0	0.0%	0	0	0	0	0	0	0	0	0
5	1	8.3%	0	0	0	0	0	1	0	0	0
6	1	8.3%	0	1	0	0	0	0	0	0	0
7	4	33.3%	1	0	0	0	3	0	0	0	0
8	2	16.7%	0	1	1	0	0	0	0	0	0
9	0	0.0%	0	0	0	0	0	0	0	0	0
10	1	8.3%	0	0	0	0	1	0	0	0	0
11	1	8.3%	0	0	0	0	0	0	0	0	1
12	1	8.3%	0	0	0	0	0	0	0	1	0
13	1	8.3%	0	0	0	1	0	0	0	0	0
	12	**100.0%**	**1**	**2**	**1**	**1**	**4**	**1**	**0**	**1**	**1**
		100.0%	**8.3%**	**16.7%**	**8.3%**	**8.3%**	**33.3%**	**8.3%**	**0.0%**	**8.3%**	**8.3%**

***** CPTRT Repeating numbers response time
CPTA Repeating numbers accuracy
CPTL Repeating numbers lapses
MTHRT Mathematical processing response time
MTHA Mathematical processing accuracy
MTSRT Pattern memory response time
MTSA Pattern memory accuracy
CDDRT Symbol memory response time
CDDA Symbol memory accuracy

Table IV. WinSCAT Summary by Subject: Off-Nominal Throughput Scores (Means)

ID	Total Off-Nominal		Off-Nominal Throughput Scores by Subtest *			
	Count	Percent	CPT	MTH	MTS	CDD
1	0	0.00%	0	0	0	0
2	0	0.00%	0	0	0	0
3	0	0.00%	0	0	0	0
4	1	12.5%	0	1	0	0
5	2	25.0%	0	0	2	0
6	0	0.00%	0	0	0	0
7	3	37.5%	0	3	0	0
8	0	0.00%	0	0	0	0
9	0	0.00%	0	0	0	0
10	0	0.00%	0	0	0	0
11	0	0.00%	0	0	0	0
12	1	12.5%	0	1	0	0
13	1	12.5%	0	0	1	0
	8	**100.0%**	**0**	**5**	**3**	**0**
		100.0%	**0.00%**	**62.5%**	**37.5%**	**0.00%**

***** CPT Repeating numbers
MTH Mathematical processing
MTS Pattern memory
CDD Symbol memory